PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : H03B 1/00, H03K 5/00	A1	(11) International Publication Number: WO 92/07422 (43) International Publication Date: 30 April 1992 (30.04.92)

(21) International Application Number: PCT/US91/05876

(22) International Filing Date: 19 August 1991 (19.08.91)

(30) Priority data:
595,062 10 October 1990 (10.10.90) US

(71) Applicant: MOTOROLA, INC. [US/US]; 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

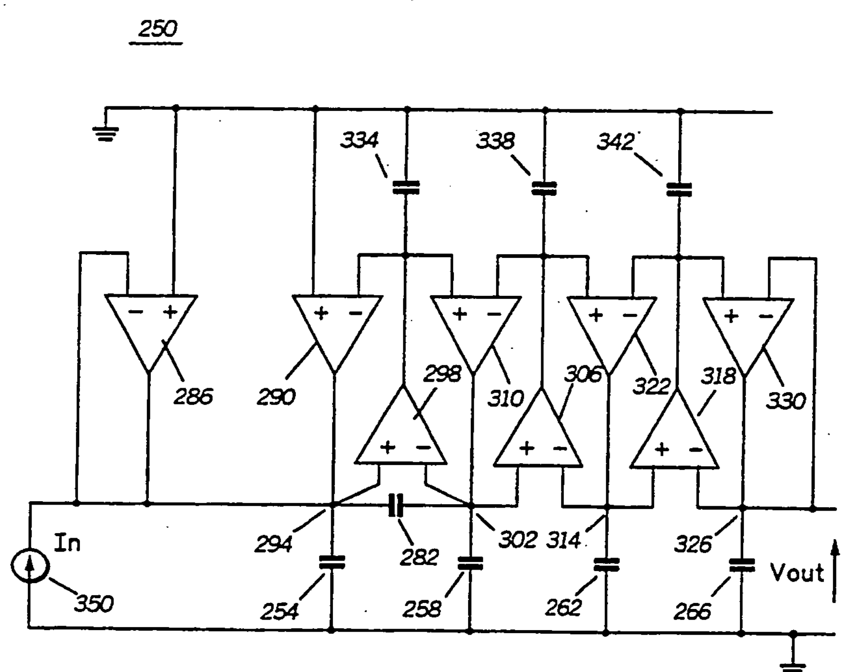
(72) Inventors: HECK, Joseph, P. ; 1940 East Oak Knoll Circle, Fort Lauderdale, FL 33324 (US). JASON, Barry, L. ; 325 Warbler Drive, Bedford, TX 76021 (US).

(74) Agents: PARMELEE, Steven, G. et al.; Motorola, Inc., Intellectual Property Dept., 1303 East Algonquin Road, Schaumburg, IL 60196 (US).

(81) Designated States: AT, BR, CA, DE, GB, JP.

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: ACTIVE FILTER CIRCUIT



(57) Abstract

A filter circuit (250) disposed upon a single integrated circuit comprised of active fiter elements including transconductance elements (286-330) for a radiotelephone. The bandwidth of the passband of the filter is variable to pass alternately, signals of either a first bandwidth or a second bandwidth for passing, for example, signals generated in a conventional, cellular communication system, or a cellular communication system of increased capacity. Fine tuning of the bandwidth of the passband of the filter permits blocking of noise signals positioned, in frequency, proximate to a received, information signal.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	ES	Spain	MG	Madagascar
AU	Australia	FI	Finland	ML	Mali
BB	Barbados	FR	France	MN	Mongolia
BE	Belgium	GA	Gabon	MR	Mauritania
BF	Burkina Faso	GB	United Kingdom	MW	Malawi
BG	Bulgaria	GN	Guinea	NL	Netherlands
BJ	Benin	GR	Greece	NO	Norway
BR	Brazil	HU	Hungary	PL	Poland
CA	Canada	IT	Italy	RO	Romania
CF	Central African Republic	JP	Japan	SD	Sudan
CG	Congo	KP	Democratic People's Republic of Korea	SE	Sweden
CH	Switzerland			SN	Senegal
CI	Côte d'Ivoire	KR	Republic of Korea	SU+	Soviet Union
CM	Cameroon	LI	Liechtenstein	TD	Chad
CS	Czechoslovakia	LK	Sri Lanka	TG	Togo
DE*	Germany	LU	Luxembourg	US	United States of America
DK	Denmark	MC	Monaco		

\+ **Any designation of "SU" has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.**

ACTIVE FILTER CIRCUIT

Background of the Invention

The present invention relates generally to filter circuitry, and, more particularly, to an active filter disposed upon an integrated circuit which has a variable, or otherwise selectable, bandwidth for passing signal portions of desired frequencies of a signal applied thereto.

The design of and use of filter circuitry for passing desired signal component portions of a signal, and for filtering undesired, signal component portions of the signal, is well known. For example, filter circuitry which performs bandpass, band reject, low pass, high pass, and combinations thereof, are all well-known. Such filter circuitry, or combinations thereof, form portions of electrical circuits to pass (or reject) signal component portions of signals applied to the filter circuitry.

Historically, filter circuitry was first comprised of passive filter components formed of coils (i.e. inductors), transformers, and capacitors. Such components were advantageously utilized to form filter circuitry having extremely accurate filter characteristics. However, such classical filter components are both expensive and bulky.

Electrical circuits, of which the filter circuits oftentimes comprise a portion, include electrical circuits forming portions of communication systems. A communication system is comprised, at the minimum, of a transmitter and a

receiver interconnected by a transmission channel upon which an information signal may be transmitted. Transmitters, receivers, and other communication system circuitry is becoming increasingly miniaturized, and competition between manufacturers thereof is becoming increasingly price-competitive. Because filter circuitry forms a portion of such devices, filter circuitry is similarly becoming increasingly miniaturized, and more price-competitive.

Therefore, filter circuitry has been developed which is both of a smaller size, and is less costly to produce, than filter circuitry comprised of classical elements. For example, some active filter circuitry components may be advantageously embodied in an integrated circuit which is both of small size, and of low cost to produce.

As mentioned hereinabove, filter circuitry frequently forms a portion of electrical circuits utilized by a communication system. One particular type of communication system, a radio communication system, is comprised of a transmitter and a receiver interconnected by a radio-frequency channel. To transmit an information signal upon the radio-frequency channel, the information signal is impressed upon a radio-frequency, electromagnetic wave by a process referred to as modulation. The radio-frequency electromagnetic wave is of a characteristic frequency within a range of frequencies which defines the radio-frequency channel.

The radio-frequency, electromagnetic wave, referred to as a carrier wave, once modulated by the information signal, is referred to as a modulated, information signal. The modulated, information signal may be transmitted through free space to transmit thereby the information between the transmitter and the receiver. Modulation techniques have been developed to create the modulated, information signal by combining the carrier wave and an information signal. Such

modulation techniques include, for example, amplitude modulation (AM), frequency modulation (FM), phase modulation (PM), and complex modulation (CM).

A receiver, forming a portion of the radio communication system, receives the modulated, information signal, once generated by the transmitter and transmitted thereby over the radio-frequency channel. The receiver includes circuitry to detect, or to recreate otherwise, the information signal modulated upon the radio-frequency, electromagnetic wave. Such circuitry is referred to as demodulation circuitry, and the process of detecting, or otherwise recreating, the information signal is referred to as demodulation. The receiver typically further includes circuitry to convert the frequency of the radio-frequency, modulated, information signal to permit proper operation of the demodulation circuitry. Usually, such circuitry converts the modulated, information signal downward in frequency, and is referred to as down conversion circuitry.

A receiver additionally contains tuning circuitry including filter circuitry forming passbands for passing signal component portions of signals received by the receiver. The receiver down conversion circuitry, and the receiver demodulation circuitry may additionally contain filter circuitry to prevent passage of undesired signals.

The broad range of frequencies at which modulated, information signals may be transmitted is referred to as the electromagnetic frequency spectrum. Regulatory authorities have divided the electromagnetic frequency spectrum into frequency bands, and the frequency bands into transmission channels upon which the modulated, information signals may be transmitted. Such regulation minimizes interference between simultaneously transmitted signals.

For example, portions of a 100 MHz band of the electromagnetic frequency spectrum which extends between

800 and 900 MHz are allocated, in the United States, for radiotelephone communication. Radiotelephones utilized in a cellular, communication system transmit and receive radio frequency, modulated information signals at frequencies within such frequency band.

Numerous base stations form the infrastructure of a cellular, communication system. A base station contains circuitry to receive and to transmit modulated, information signals. By positioning base stations at spaced-apart locations throughout a geographical area, reception and transmission of modulated, information signals to and from radiotelephones located in the vicinity of individual ones of the base stations to permit two-way communication therebetween. Appropriate positioning of the base stations at the spaced-apart locations throughout the geographical area causes at least one of the base stations to be within the transmission/reception range of a radiotelephone located at any position within the geographical area. A portion of the geographical area proximate to a base station is referred to as a "cell", and each base station defines thereby a cell. Numerous cells defined by each of the numerous base stations forms the cellular communication system throughout the geographical area.

Although numerous modulated, information signals may be transmitted simultaneously upon different transmission channels (i.e., at different transmission frequencies), each modulated, information signal occupies a finite portion of the allocated frequency band, i.e., a transmission channel, and only a limited number of transmission channels in the allocated frequency band are available to permit simultaneous transmission thereupon.

Increased usage of cellular, communication systems has resulted, in many instances, in full utilization of every available transmission channel of the allocated frequency band. As a result, various suggestions have been proposed to

utilize more efficiently the frequency band allocated for radiotelephone communication. More efficient utilization of the frequency band would increase the information transmission capacity of a radiotelephone communication system. Various suggestions have similarly been proposed to use more efficiently other frequency bands of the electromagnetic frequency spectrum allocated for other uses.

A modulated, information signal is spread-out over a band of frequencies centered at, or close to, the frequency of the carrier wave. This span of frequencies over which the modulated, information signal is spread is referred to as the bandwidth of the signal. The bandwidths of the radio-frequency transmission channels into which the frequency band allocated for cellular communications is divided, must be of sizes such that modulated, information signals transmitted simultaneously over adjacent transmission channels do not overlap. However, the transmission channels must be wide enough to permit transmission of the entire modulated, information signals thereupon, but additionally, permit a certain amount of frequency drift of the signals as the signals are transmitted upon the transmission channels. That is, the channel spacing defining the transmission channel bandwidths must be great enough to permit frequency drift of simultaneously-transmitted, modulated, information signals on an adjacent channels in which one, or more, of the signals exhibit frequency drift.

Transmitter circuitry of transmitters which generate and transmit the modulated, information signals upon the transmission channels, generate signals which are somewhat smaller than the channel bandwidth. The channel bandwidth is wide enough to permit simultaneous transmission of signals on adjacent channels even when there is significant frequency drift (as a percentage of the bandwidth of the

transmitted signal) of the signals transmitted upon the adjacent channels.

As commercially-viable methods and apparatus for reducing signal bandwidth of transmitted signals, and for minimizing frequency drift of the transmitted signals are developed and implemented, the bandwidths of the transmission channels upon which the signals are transmitted may be reduced. A reduction in the bandwidths of the transmission channels would permit a greater number of transmission channels to be defined for a frequency band, such as the frequency band allocated for cellular communications. For instance, in the United States, a portion, extending between 824 MHz and 849 MHz, is allocated for the transmission of modulated information signals from a radiotelephone to a base station. A second portion, extending between 869 MHz and 894 MHz of the frequency band is allocated for the transmission of modulated information signals from a base station to radiotelephone. Each of the transmission channels of the first and second portions of the allocated frequency band is of a bandwidth of 30 KHz. By reducing the size of the bandwidths of the transmission channels from 30 KHz to 15 KHz would result in a doubling of capacity of a cellular communication system within a particular geographical area. The conventional-sized transmission channel is referred to as a wideband bandwidth channel, and the transmission channel of reduced size is referred to as a narrowband bandwidth.

Such a reduction in transmission channel bandwidths, however, requires alteration of the infrastructure (that is, the base stations) as well as the radiotelephones utilized in such a system. Because such an alteration of the infrastructure necessitates significant capital expenditures, only those cellular communication systems which are presently, or are anticipated to be, fully utilized, need to be altered to permit

greater numbers of the transmission channels to be defined therein. However, to permit operation of a radiotelephone in both existing cellular communication systems and cellular communications systems in which the capacity thereof is increased, the radiotelephones must contain circuitry to permit operation thereof in either an existing system or a system of expanded capacity.

To permit operation of a single radiotelephone in both existing systems and systems of expanded capacity requires circuitry to permit reception of either signals of normal bandwidths, or signals of reduced bandwidths. Most simply, such a radiotelephone could be designed to have separate filter circuitry, each having passbands of different bandwidths (i.e., both the wideband bandwidth and the narrowband bandwidth). One or the other of the filter circuitry would be operative depending upon, for example, in which system the radiotelephone is located, or depending upon the bandwidth of the signal transmitted thereto. However, because of the increased miniaturization of radiotelephones, the utilization of additional filter circuitry would limit further miniaturization of the radiotelephone. Therefore, a single filter circuit which is operable to pass either a modulated information signal of normal bandwidth, or, alternately, a modulated information signal of reduced bandwidth would be beneficial.

What is needed, therefore, is a radiotelephone construction having filter circuitry, of minimal size, which permits reception of modulated, information signals of bandwidths corresponding to the bandwidths of signals generated in a conventional, cellular communication system, or a cellular, communication system of increased capacity.

Summary of the Invention

It is, accordingly, an object of the present invention to provide filter circuitry having a variable passband for permitting reception of a signal of either a first bandwidth, or a second bandwidth.

It is a further object of the present invention to provide filter circuitry having a variable passband for a radiotelephone to permit thereby reception of both a wideband signal and a narrowband signal.

It is a yet further object of the present invention to provide active filter circuitry, disposed upon an integrated circuit, having a variable bandwidth.

In accordance with the present invention, therefore, an active filter circuit having a variable passband operative to pass signal portions of a received signal is disclosed. The filter circuit is disposed upon an integrated circuit and comprises a filter defining at least one passband of a desired bandwidth having an upper cut-off frequency and a lower cut-off frequency for passing signal portions of a received signal having frequencies within the desired bandwidth. The desired bandwidth of the passband of the filter is selected by the application of a control signal to the filter.

Brief Description of the Drawings

The present invention will be better understood when read in light of the accompanying drawings in which:

FIGs. 1A and 1B are graphical representations of a typical, modulated, information signal graphed as a function of frequency;

FIG. 2 is a graphical representation of several adjacent transmission channels of the frequency band allocated for

cellular communications formed of a portion of the electromagnetic frequency spectrum;

FIG. 3 is a graphical representation, similar to that of FIG. 2, but illustrating the simultaneous transmission of modulated, information signals upon adjacent channels of the a cellular, communication system wherein signals of bandwidths representative of a conventional, cellular communication system are shown at the left-hand side portion of the figure, and signals representative of signals generated in a cellular communication system of expanded capacity are shown in the right-hand side portion of the figure;

FIG. 4 is a graphical representation of a modulated, information signal transmitted upon a transmission channel in which a noise, or other undesired, signal is located, in frequency, proximate thereto;

FIG. 5 is a circuit schematic of an LC filter circuit which forms a passband of a bandwidth and cutoff frequencies of values determined by the values of the component elements thereof;

FIG. 6 is a circuit schematic of a filter circuit, similar to that of FIG. 5, but having transconductance elements and capacitors comprising the component elements thereof; and

FIG. 7 is a block diagram of a radiotelephone of the present invention in which the filter of FIG. 6 forms a portion thereof.

Description of a Preferred Embodiment

Turning first to the graphical representation of FIG. 1A, a modulated, information signal, referred to generally by reference numeral 10, is plotted as a function of frequency. The amplitude of signal 10, scaled in terms of volts on ordinate axis 14, is graphed as a function of frequency, scaled in terms of hertz, on abscissa axis 18. Signal 10 is representative of the

signal formed by modulating an information signal by one of the previously-mentioned modulation techniques, for example, an AM, FM, PM, or CM technique.

The energy of the modulated, information signal, such as signal 10, formed by one of these modulation techniques is typically centered about a center frequency, f_c of a particular frequency. The center frequency, in most instances, is the carrier frequency. The resultant, modulated, information signal, here signal 10, is symmetrical about the center frequency, f_c. Vertically-extending line 22, shown in hatch, which is defined by the center frequency,f_c, indicates such symmetry of signal 10 thereabout.

The bandwidth of signal 10 is indicated by the length of arrow 26. A receiver circuit which receives a modulated, information signal, such as signal 10, includes filter circuitry having passbands at least as wide as the bandwidth of the modulated, information signal to recreate, in undistorted form, the information signal. Because of frequency drift associated with the transmission of radio-frequency signals, the bandwidth of the filter circuitry of the receiver is typically greater than the bandwidth of the transmitted signal.

The graphical representation of FIG. 1B is similar to that of FIG. 1A in which modulated information signal 10 is plotted as a function of frequency. The amplitude of signal 10, scaled in terms of volts on ordinate axis 14, is graphed as a function of frequency, scaled in terms of hertz, on abscissa axis 18. The graph of FIG. 1B further illustrates signal 30 characterized by frequencies close to the frequencies encompassed by the bandwidth of signal 10. Signal 30 is representative of, for example, a spurious noise signal or a modulated, information signal transmitted upon a transmission channel adjacent to the transmission channel upon which signal 10 is transmitted, but which has drifted in frequency. For purposes of illustration, the amplitude of

signal 30 is greater than the amplitude of signal 10. Signal 30 may alternately be of an amplitude equal to or less than the amplitude of the signal 10.

Ideally, a receiver constructed to receive signal 10 contains filter circuitry having passbands of bandwidths to receive signal 10 in undistorted form, but to prevent passage of unwanted signals, such as signal 30. However, as mentioned hereinabove, the passbands of the filter circuitry of a receiver are typically greater than the bandwidth of the modulated, information signal (here, signal 10) to ensure that the entire signal is passed in undistorted form even when significant frequency drift of the transmitted signal occurs. Such an enlarged bandwidth is indicated in FIG. 1B by arrow 34. Filter circuitry having a passband corresponding to the bandwidth indicated by arrow 34 permits passage of signal 10 in undistorted form, but, additionally, permits passage of unwanted signals su h as, and as indicated in the Figure, a portion of signal 30. In instances, and as illustrated in FIG. 1B, in which the unwanted signal is of a significant amplitude relative to the amplitude of signal 10 (here, signal 30 is of an amplitude greater than the amplitude of signal 10), the resultant signal recreated by a receiver would contain significant interference, caused by the unwanted signal or portion thereof. Therefore, it would be desirable to be able to decrease the bandwidth of the passbands of the filter circuitry, as desired, to prevent passage of unwanted signals located in frequency close to a modulated, information signal.

Turning now to the graphical representation of FIG. 2, a portion of a frequency band representative of a portion of the frequency band allocated for cellular communications is illustrated. Similar to the graph of FIG. 1, the ordinate axis, here axis 38, is scaled in terms of volts and abscissa axis, here axis 42, is scaled in terms of hertz. As mentioned previously, portions of the frequency band allocated for cellular

communication are divided into transmission channels whereupon a single signal is transmitted at a time upon any, or all, of the transmission channels to prevent overlapping of simultaneously transmitted signals. Signals transmitted upon adjacent, or other, transmission channels may, of course, be simultaneously transmitted.

FIG. 2 illustrates five of such transmission channels, here referred to by reference numerals 46, 50, 54, 58, and 62. In FIG. 2, each transmission channel 46-62 is of a 30 KHz bandwidth. Such a bandwidth corresponds to the bandwidths defined for transmission channels of existing, United States, cellular communication systems. Transmission channels defined upon other cellular, communications systems may be similarly illustrated with appropriate substitution of other transmission channel bandwidths. For instance, the transmission channels defined in existing, Japanese, cellular communications systems of are 25 KHz bandwidths. Other channelized communications systems may similarly be described with appropriate substitution of frequency demarcations.

The vertical lines spaced at the 30 KHz intervals represent boundaries between adjacent ones of the transmission channels 46-62. Modulated, information signals, such as signal 10 of FIGs. 1A and 1B may be transmitted simultaneously upon any or all of the transmission channels 46-62 as long as the bandwidths of the signals transmitted upon individual ones of the channels 46-62 are not of sizes to overlap with signals transmitted upon adjacent ones of the transmission channels.

Control of the bandwidths of the signals transmitted is required, not only to prevent overlapping of simultaneously transmitted signals, but, additionally, because the passbands of the receiver filter circuitry are, in most instances, of magnitudes corresponding to the bandwidths of the

transmission channels. If a signal transmitted upon one of the transmission channels is of too large of a bandwidth, or the frequency drift of the signal causes the transmitted signal to be partially, or wholly, beyond the passband of the filter circuitry, the signal demodulated by the receiver will be distorted.

Signals 66 and 70 are positioned within channels 46 and 50, respectively, of FIG. 2. Signals 66 and 70 are similar in shape and bandwidth to signal 10 of FIGs. 1A-1B, and are representative of modulated, information signals generated and transmitted by a conventional transmitter. Further illustrated in FIG. 2 is signal 74 positioned within the boundaries of transmission channel 54. Signal 74 is representative of a modulated, information signal generated and transmitted by a transmitter of a newer construction and is of a bandwidth of one-half of the size of the bandwidth of signal 66 and 70. While methods and apparatus for transmitting small bandwidths signals have been previously available, technical improvements have permitted the construction of commercially-viable transmitters capable of transmitting signals of such reduced bandwidths.

Historically, the channel spacing determining channel bandwidths of the transmission channels, such as transmission channels 46-62 of FIG. 2, of the frequency band allocated for cellular communications was defined to ensure that transmitters utilizing commercially-viable technology could transmit channels of bandwidths less than the bandwidths of the transmission channels. As illustrated, however, the bandwidth requirements of signals generated and transmitted by newer, and now commercially-viable, transmitters permits significant portions of each channel of the frequency band allocated for cellular communications to be unused. However, by re-defining the bandwidths of the channels of the allocated frequency band to reduce thereby the

bandwidths of some, or all, of the channels, greater numbers of channels may be defined over the allocated frequency band. Greater numbers of signals could then be transmitted simultaneously upon the increased number of transmission channels, thereby increasing the transmission capacity of the cellular, communication system.

FIG. 3 is graphical representation, similar to that of FIG. 2, defining an axis system wherein ordinate axis 38 is scaled in terms of volts, and abscissa axis 42 is scaled in terms of hertz. Similar to FIG. 2, the transmission channels of FIG. 3 have boundaries represented by vertically extending lines. The left-hand side portion of the Figure illustrates transmission channels 78 and 82 of bandwidths similar to the bandwidths of transmission channels 46-62 of FIG. 2. Signals 86 and 90 of bandwidths similar to the bandwidths of signals 66 and 70 of FIG. 2 are again representative of signals generated and transmitted by transmitters of conventional construction. The right-hand side portion of FIG. 3, however, illustrates four transmission channels 94, 98, 102, and 106, of bandwidths one-half the size of the bandwidths of transmission channels 78 and 82. Transmitted upon channels 94-106 are signals 110, 114, 118, and 122. Signals 110-122 are of bandwidths similar to the bandwidths of signal 74 of FIG. 2, and, therefore, are of bandwidths of one-half of the size of the bandwidths of signals 86 and 90. Comparison of the left-hand side portion and the right-hand side portion of the graph of FIG. 3 illustrates that twice the number of the signals may be simultaneously transmitted in a system in which the transmission channels, and the signals transmitted thereupon, are one-half the size of the transmission channels of a conventional system.

Because the number channels of the right-hand side portion of FIG. 3 is a multiple of the channels of the left-hand side portion thereof, the channel spacing of the right-hand side portion of the Figure is compatible with the channel

spacing of the left-hand side portion thereof. A cellular, communication system may therefore form a system in which transmission channels of more than one bandwidth may be defined. It is noted that a system in which the channels of another multiple (such as, for example, a multiple of three) would similarly define a system compatible with existing systems.

In order to properly recreate the information signal portion of a transmitted signal, radiotelephone receiver circuitry should contain filter circuitry for passing only the desired signal. Because, as previously mentioned, the receiver contains filter circuitry having passbands corresponding to the bandwidths of the transmission channels upon which a signal is transmitted, a receiver of a radiotelephone operable in either a conventional system or a system of increased capacity would require filter circuitry having passbands corresponding to the bandwidths of transmission channels of a conventional system, and of bandwidths corresponding to a system of increased capacity. Because of the ever-increasing miniaturization of electronic goods, such as radiotelephones, it would be desirable to have a radiotelephone construction having a single filter circuit capable of forming a passband of a variable bandwidth.

FIG. 4 illustrates a single transmission channel 126 upon which modulated, information signal 130 is transmitted. Positioned proximate to signal 130, in frequency, is noise signal 134. A portion of signal 134 is within the bandwidth of transmission channel 126. A radiotelephone construction having filter circuitry capable of forming a variable passband is additionally advantageous for the reason that the passband of the filter may be reduced to prevent passage of those portions of noise signal 134 having frequencies within the range of frequencies defined by the passband of transmission channel 126. That is, the passband of the filter circuitry may be

adjusted, or fine-tuned, to prevent passage of the noise portions, when present.

Turning now to circuit diagram of FIG. 5, an LC filter circuit, referred to generally by reference numeral 150, is shown. Filter circuit 150 is formed by capacitors 154, 158, 162, and 166 positioned in a parallel connection wherein first sides of capacitors 154 and 158 are connected through inductor 170, first sides of capacitors 158 and 162 are connected through inductor 174, and first sides of capacitors 162 and 166 are interconnected by inductor 178. Capacitor 182 is additionally positioned in parallel with inductor 170 between first sides of capacitors 154 and 158. Second sides of capacitors 154-166 are suitably connected there together, and preferably, and as illustrated, are coupled to a ground connection. Filter circuit 150 further illustrates current source 186 connected in a parallel connection with resistor 190, and additionally in parallel with the parallel connection of capacitors 154 -166. Current source 186 may be representative of a wideband, received signal which is received by a radiotelephone. Filter circuit 150 of FIG. 5 further includes resistor 194 connected in parallel with capacitor 166 across which an output voltage may be measured. Filter circuit 150 forms a passband of a frequency bandwidth determined by the values of capacitors 154-166 and 182, and inductors 170-178. The passband of the filter circuit 150 may, of course, be altered by altering the values of the component elements thereof.

Turning now to circuit schematic of FIG. 6, a circuit equivalent to filter circuit 150, here referred to generally by reference numeral 250, is shown. Equivalent filter circuit 250 is comprised by circuit component elements formed of capacitors and transconductance elements. Transconductance elements of the equivalent filter circuit 250 are substituted for the inductors 170-178 of the filter circuit 150 of FIG. 5 for reasons to be discussed more fully hereinbelow.

Similar to capacitors 154-166 and 182 of filter circuit 150 of FIG. 5, equivalent filter circuit 250 includes capacitors 254, 258, 262, and 266 which are connected in a parallel connection. Connecting first sides of capacitors 254 and 258 is capacitor 282. Second sides of capacitors 254-266 are suitably connected theretogether, and preferably, as illustrated, are connected to ground potential.

Outputs of transconductance elements 286 and 290 are coupled to node 294 (which further has first sides of capacitors 254 and 282 connected thereat). A negative input of transconductance element 286 and a positive input of transconductance element 298 is further coupled at node 294. A negative input to transconductance element 298 is coupled to node 302 as is a positive input to transconductance element 306, and the output of transconductance element 310 (additionally, second side of capacitor 282 and first side of capacitor 258 are coupled thereat). Similarly, a negative input to transconductance element 306 is coupled to node 314 as is a positive input of transconductance element 318, and the output of transconductance element 322 (additionally, first side of capacitor 262 is coupled to node 314). A negative input to transconductance element 318 is coupled at node 326 as are the output and input of transconductance element 330.

Positive inputs to transconductance elements 286 and 290 are coupled directly to ground; a negative input to transconductance element 290 is coupled to ground through capacitor 334 as is the positive input to transconductance element 310. The negative input to transconductance element 310 is coupled to ground through capacitor 342 as is the positive input to transconductance element 322. The negative input to transconductance element 322 is coupled to ground through capacitor 338 as is the positive input to transconductance element 330. Outputs of transconductance

elements 298, 306 and 318 are coupled to ground through capacitors 334, 338, and 342.

The use of transconductance elements as component elements of equivalent filter circuit 250 is advantageous for the reason that transconductance elements may be easily disposed upon an integrated circuit. Additionally, the characteristics of transconductance elements may be quickly altered to alter thereby the characteristics, namely, the passband, of the equivalent filter circuit 250 formed thereby. Filter circuit 250 of FIG. 6 further illustrates current source 350 which, similar to current source 186 of FIG. 6 may correspond to a wideband, receive signal received by a radiotelephone receiver.

The integrated circuit upon which filter circuit 250 is disposed, according to the preferred embodiment of the present invention, further has disposed thereupon an oscillator, which is also comprised of transconductance elements. Tracking between elements, and particularly the transconductance elements, upon a single integrated circuit is a well known phenomena. Such tracking between the transconductance elements forming a portion of filter circuit 250 and transconductance elements forming a portion an oscillator may be advantageously utilized to maintain the relative frequencies of the passbands of the filter formed of filter circuit 250 and the oscillating frequency of the oscillator disposed upon the integrated circuit with the same external reference, such as an external crystal oscillator. Thereby, the cut-off frequencies of the passband formed of filter circuit 250 may be precisely controlled.

Appropriate control signals may be applied to the transconductance elements of the filter circuit 250 to vary the passband of the filter circuit to pass signals within bandwidths of transmission channels, such as transmission channels 78 and 82 of a conventional, cellular communication system illustrated in FIG. 3, or, alternately, to be of a passband of

bandwidths corresponding to the transmission channels of a cellular, communication system of increased capacity, such as transmission channels 94-106 of FIG. 3. Variation (i.e., fine tuning) of the actual bandwidths of the passbands of the filter circuit 250 may additionally be adjusted responsive to the presence of noise, such as noise signal 134 of FIG. 4, proximate in frequency, to a desired signal, such as signal 130 of FIG. 4. The existence of such noise may be indicated, for example, by determining, and monitoring a ratio of signal plus noise-to-noise and distortion (a signal commonly referred to as a SINAD signal), or a conventional, RSSI signal, the generation of either of which are well known per se in the art.

Turning now to the block diagram of FIG. 7, a radiotelephone, referred to generally by reference numeral 400, constructed according to the teachings of the present invention is illustrated. The actual circuitry embodying the functional blocks of the diagram may be disposed upon one or more circuit boards and housed within a conventional radiotelephone housing.

Radiotelephone 400 utilizes the active filter circuit of FIG. 6 comprised of transconductance elements and capacitors to form a variable filter of a passband of a desired bandwidth thereby. The use of such filter circuitry permits operation of radiotelephone 400 to receive signals transmitted in a conventional, cellular communication system, or, alternately, in a cellular, communication system of increased capacity. A transmitted signal transmitted by a base station, here represented by transmitter 404, is received by radiotelephone antenna 408.

Antenna 408 supplies the received signal on line 412 to preselector/filter 416. Preselector/filter 416 is preferably a very wideband filter having a passband to pass all of the frequencies within a band of interest. Filter 416 generates a filtered signal on line 420 which is supplied to mixer 424.

Mixer 424 additionally receives an oscillating signal on line 428 from injection filter 432, which is, in turn, supplied an oscillating, input signal on line 436 by oscillator 440. Oscillator 440 is locked in frequency with the oscillating frequency of oscillator 444 which, for example, may be comprised of a crystal oscillator. Oscillator 440 and filter 432 may together form a portion of a conventional phase locked loop. Mixer 424 generates a down converted signal (commonly referred to as a first intermediate, frequency, i.e., IF, signal) on line 448 which is supplied to filter 452. Filter 452 is, preferably, and as illustrated, a monolithic crystal wideband filter (commonly referred to as the first intermediate frequency, i.e., IF, filter).

Filter 452 generates a filtered signal on line 456 which is supplied to amplifier 460. Amplifier 460 amplifies the signal supplied thereto on line 456 and generates an amplified signal on line 464. Line 464 is coupled to an input of mixer 468 which also receives an input on line 472 from oscillator 476. As mentioned hereinabove, oscillator 476 is preferably disposed upon an integrated circuit, and such integrated circuit is indicated in the figure by block 480, shown in hatch. The oscillating frequency of oscillator 476 is locked to the oscillating frequency of oscillator 444 by the connection therebetween by line 484. Mixer 468 generates a mixed signal on line 488 which is supplied to filter 492. Filter 42, referred to as the second intermediate frequency filter, is similar to the equivalent filter circuit of FIG. 6, and is disposed upon the same integrated circuit as oscillator 476 (as indicated by block 480, shown in hatch). Control signal inputs to filter 492 are indicated by lines 496, 500, and 504, which correspond to an external input signal for selecting the bandwidth of filter 492 to pass a signal transmitted by a conventional, cellular, communication system or one of increased capacity, a SINAD signal, and an RSSI signal, respectively. As mentioned hereinabove, the SINAD and RSSI signals supplied on lines 500 and 504 fine

tune the bandwidth of the passband of filter 492. Filter 492 generates a filtered signal on line 508 which is supplied to limiter 512. Limiter 512 generates a voltage-limited signal on line 516 which is supplied to the demodulator 520. Demodulator 520 is comprised of conventional demodulation circuitry for demodulating the signal supplied thereto and providing an output on line 524.

The signal supplied of line 496 may, for example, cause the filter to be of a first bandwidth when the signal is beneath a certain value, and be of a second bandwidth when the signal is beyond the certain value. Additionally, filter passbands of three (or even more) different bandwidths responsive to values of the signal supplied to filter 492 on line 496 may be formed. for example, when the signal on line 496 is beneath a first level, a narrowband filter may be selected, when the signal on line 496 is beyond a second level, a wideband filter may be selected, and when the signal on line 496 is between the first and the second levels, a midband filter having a passband of a bandwidth less than the wideband filter, but greater than the bandwidth of the narrowband filter, may be selected.

Because the bandwidth of the passband of filter 492 is variable, a single filter circuit disposed upon a single integrated circuit may be utilized to permit reception of a signal generated by a transmitter of a conventional, cellular communication system, or of a cellular, communication system of increased capacity. Fine tuning of the bandwidth of the passband to minimize signal degradation and other problems associated with noise is facilitated by the application of the SINAD and RSSI signals on lines 500 and 504. Still further, because of the tracking of the transconductance elements of both oscillator 476 and filter 492 disposed upon the single integrated circuit 480, precision of the actual cut-off frequencies which define the bandwidth of the passband of filter 492 may be controlled.

While the present invention has been described in connection with the preferred embodiments of various figures, it is to be understood that similar embodiments may be used and modifications and additions may be made to the described embodiments for performing the same functions of the present invention without deviating therefrom. Therefore, the present invention should not be limited to any single embodiment, but rather construed in breadth and scope in accordance with the recitation of the appended claims.

What is claimed is:

Claims

1. An active filter circuit having a variable passband operative to pass signal portions of a received signal, said filter circuit disposed upon an integrated circuit, said filter circuit comprising: means forming a filter defining at least one passband of a desired bandwidth having an upper cut-off frequency and a lower cut-off frequency for passing signal portions of the received signal having frequencies within said desired bandwidth; and means for selecting the desired bandwidth of the passband of the filter formed by said means for passing responsive to application of a control signal thereto.

2. The active filter circuit of claim 1 wherein the filter comprises transconductance elements.

3. The active filter circuit of claim 2 further comprising means forming an oscillator disposed upon the integrated circuit for generating an oscillating signal having an oscillating frequency of a known value.

4. The active filter circuit of claim 3 wherein values of the transconductance elements, which comprise the filter, track the oscillating frequency of the oscillating signal generated by the oscillator.

5. The active filter circuit of claim 4 wherein the filter and the oscillator are disposed upon a single integrated circuit chip.

6. The active filter circuit of claim 1 wherein the control signal applied to the means for selecting is indicative of the signal strength of the received signal.

7. The active filter circuit of claim 1 wherein the control signal applied to the means for selecting is indicative of a value of a signal to noise ratio formed by determining the ratio of the magnitude of the received signal exclusive of a noise component to the magnitude of the received signal inclusive of a noise component.

8. The active filter circuit of claim 1 wherein the control signal applied to the means for selecting is indicative of a bandwidth of an information signal forming a portion of the received signal.

9. The active filter circuit of claim 8 wherein the filter formed by the means for passing is operative alternately to pass signal portions of a received signal within a first frequency bandwidth or signal portions of a received signal within a second frequency bandwidth.

10. The active filter circuit of claim 9 wherein the filter passes signal portions of the received signal within said first frequency bandwidth when said control signal is of a value beneath a predetermined value, and the filter passes signal portions of the received signal within said second frequency bandwidth when said control signal is of a value beyond the predetermined value.

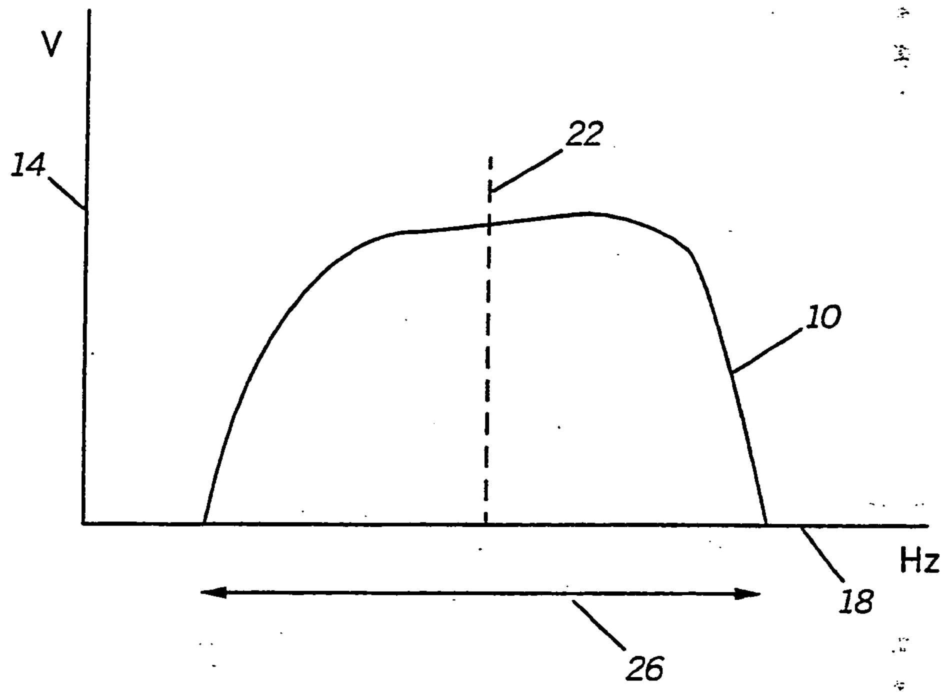


FIG.1A

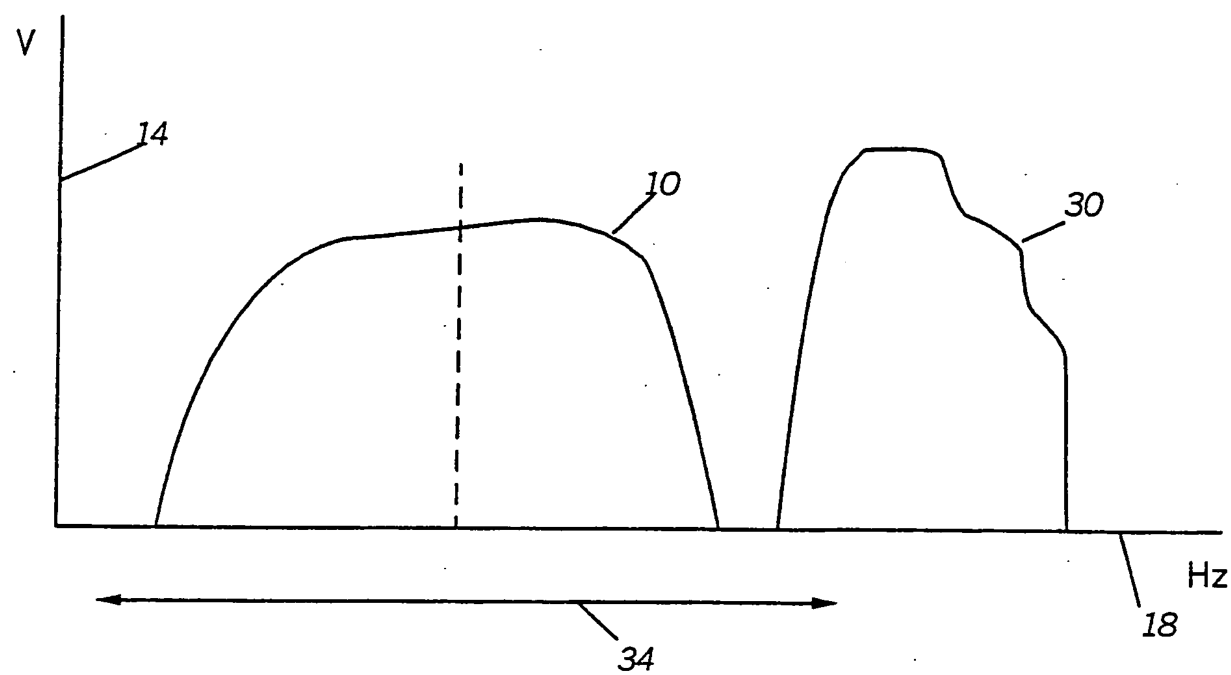


FIG.1B

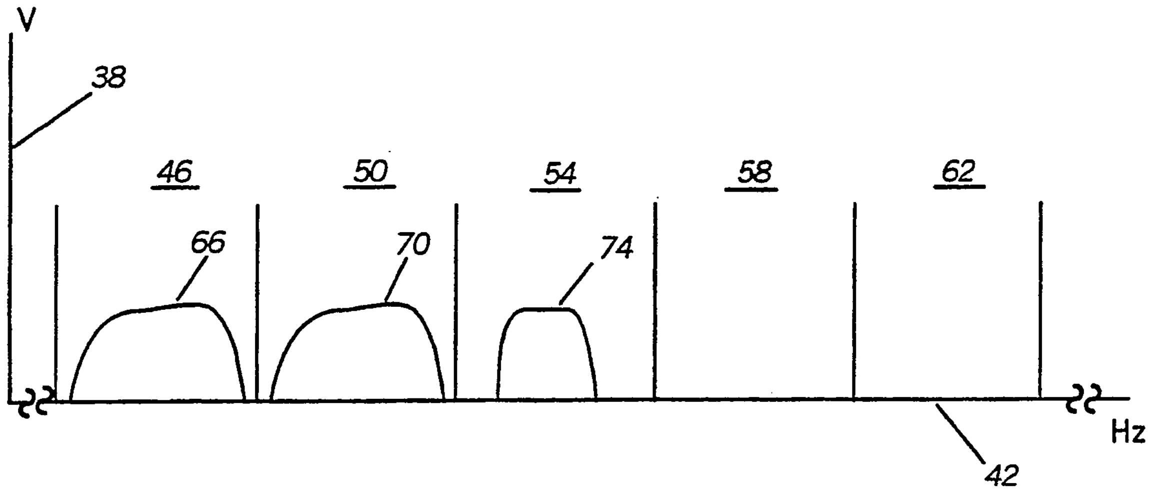

V
38
46
50
54
58
62
66
70
74
Hz
42

FIG.2

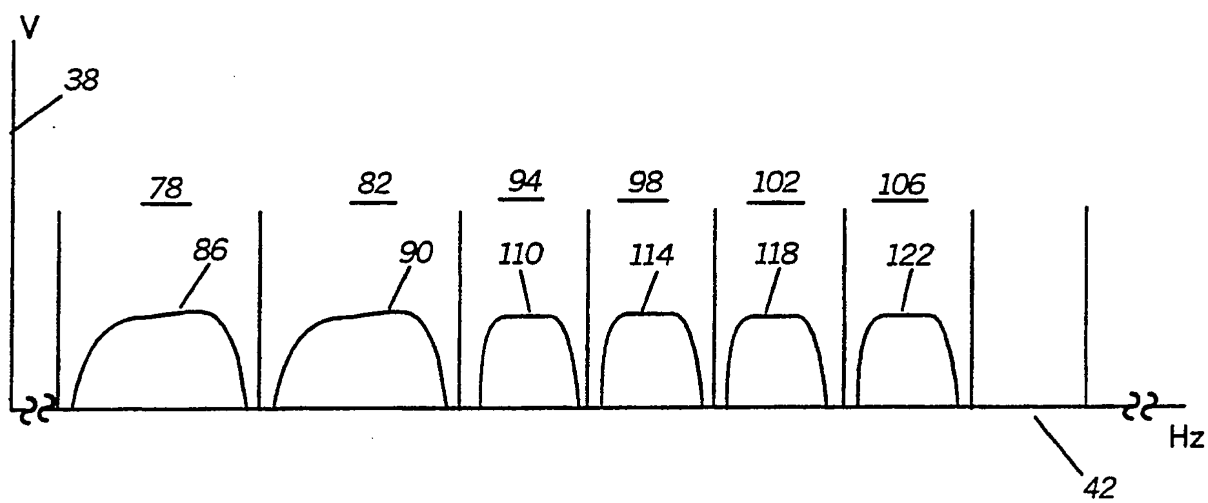

V
38
78
82
94
98
102
106
86
90
110
114
118
122
Hz
42

FIG.3

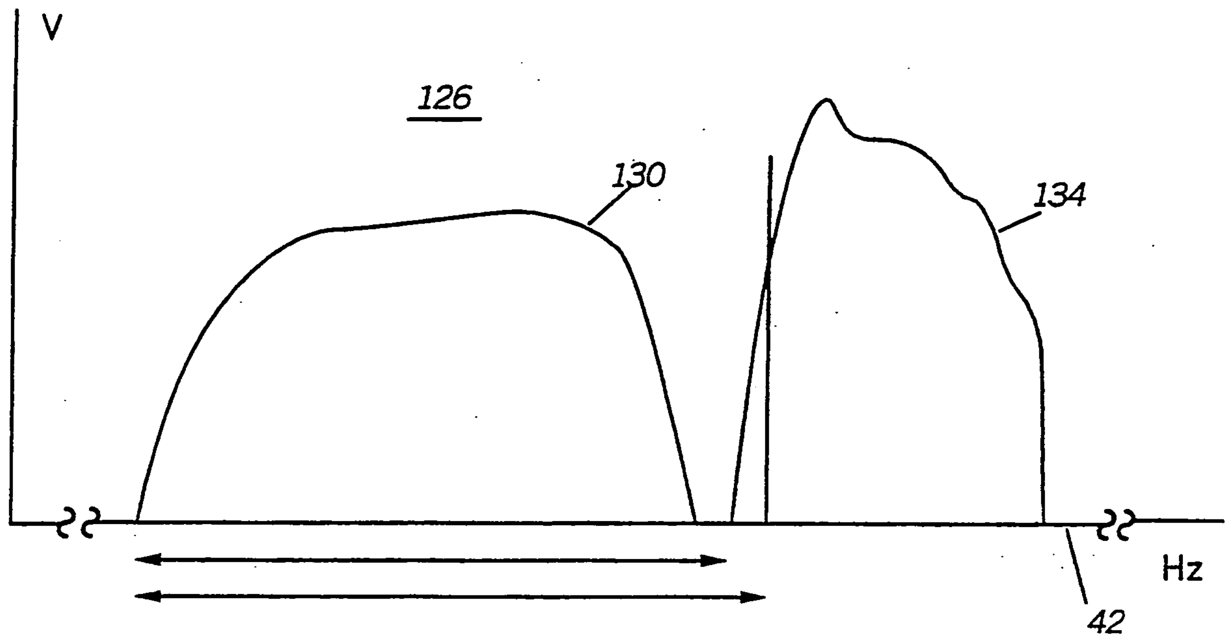

V
126
130
134
Hz
42

FIG.4

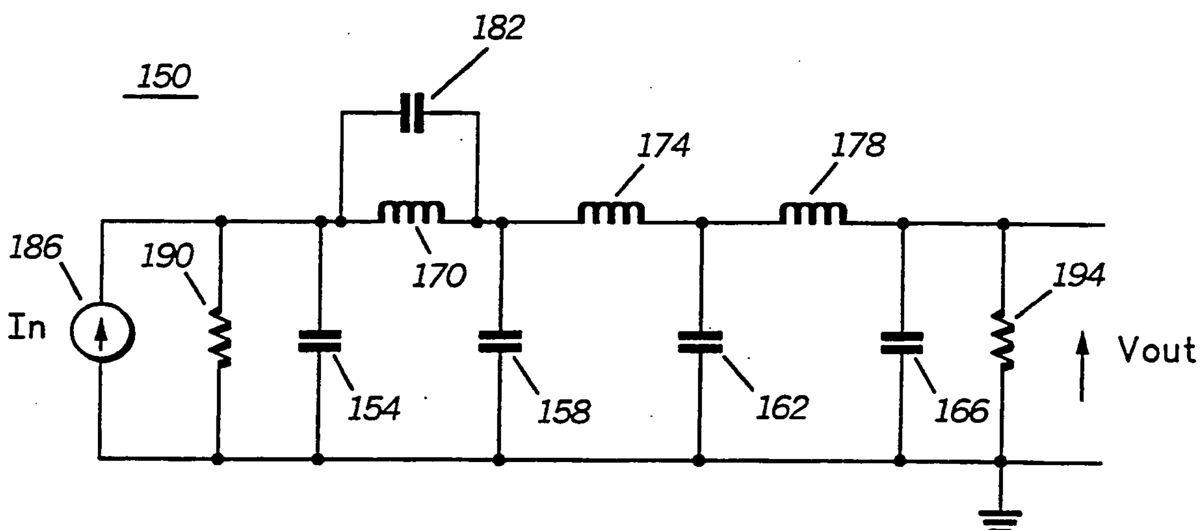

182
150
174
178
186
190
170
194
In
Vout
154
158
162
166

FIG.5

FIG.6

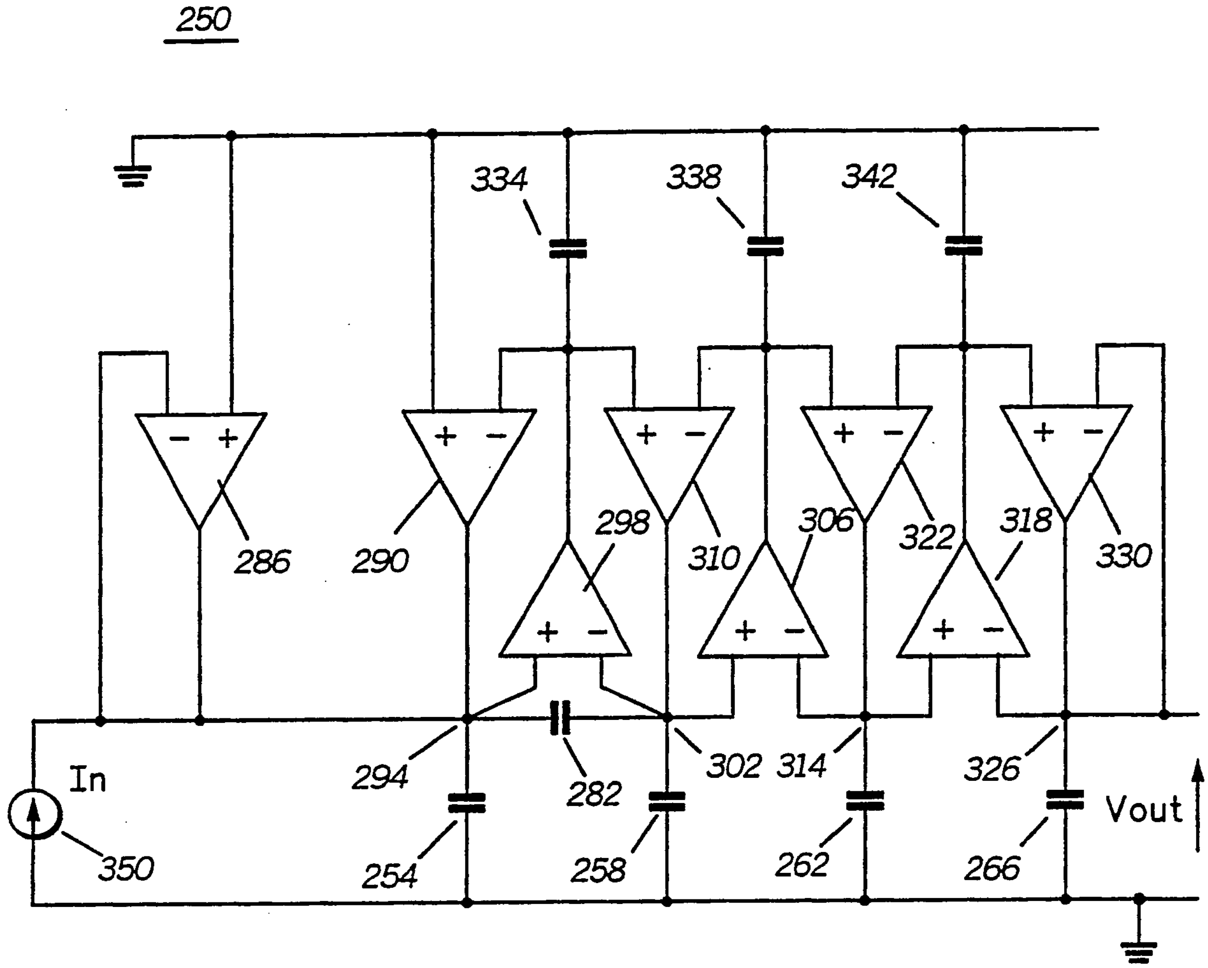
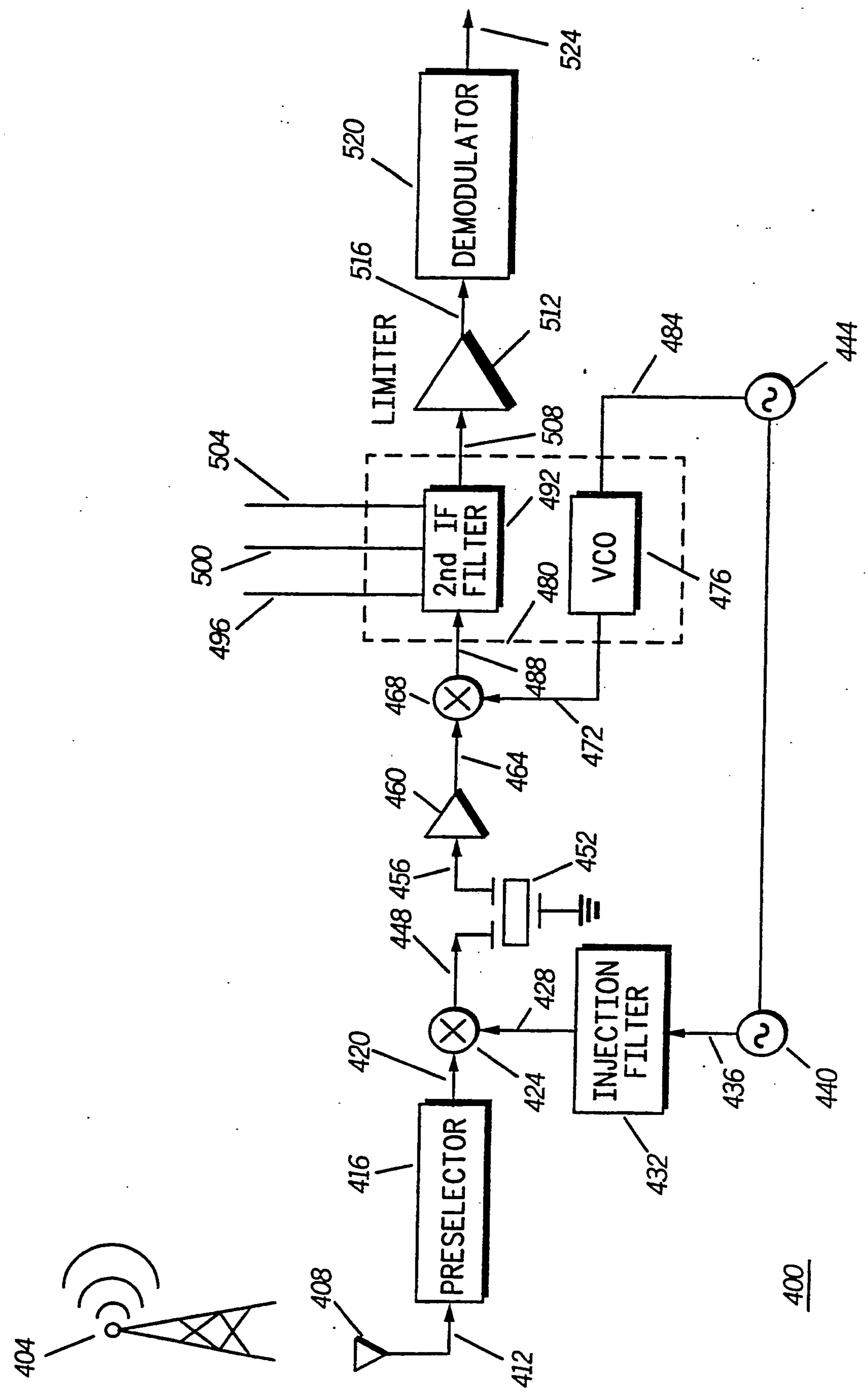

250
334
338
342
286
290
298
310
306
322
318
330
In
294
282
302
314
326
350
254
258
262
266
Vout

FIG. 7


PRESELECTOR
INJECTION FILTER
2nd IF FILTER
VCO
LIMITER
DEMODULATOR
400
404
408
412
416
420
424
428
432
436
440
444
448
452
456
460
464
468
472
476
480
484
488
492
496
500
504
508
512
516
520
524

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US91/05876

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5): H03B 1/00 H03K 5/00
U.S. CL: 307/520, 521; 328/167; 455/150

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
U. S.	307/520, 521 328/167 455/150, 182, 257

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 3,805,091, (COLIN) 16 APRIL 1974 See Entire Document.	1 and 2
X	US, A, 4,374,335 (FUKAHORI ET. AL.) 15 FEBRUARY 1983 See Entire Document.	1 - 5

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
06 MARCH 1992	17 MAR 1992
International Searching Authority	**Signature of Authorized Officer**
ISA/US	Veronica Scales for TIMOTHY P. CALLAHAN

Form PCT/ISA/210 (second sheet) (Rev.11-87)